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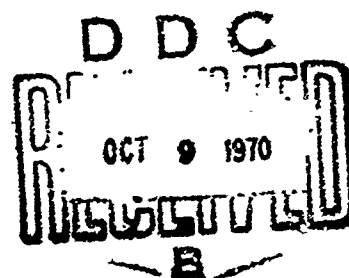NAVAL FACILITIES ENGINEERING COMMAND

DYNAMIC TESTING OF LOAD
HANDLING WIRE ROPE AND
SYNTHETIC ROPE (U)

January 1970

An Investigation Conducted by

Preformed Line Products Company
5318 St. Clair Avenue
Cleveland, Ohio   44103
Project No. M7009-T

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TEST REPORT

DYNAMIC TESTING OF LOAD HANDLING
WIRE ROPE AND SYNTHETIC ROPE (U)
NAVAL CIVIL ENGINEERING LABORATORY
N62399-69-C-0013
PROJECT NO. M9009-T

ABSTRACT

A testing program was initiated by U. S. Naval Civil Engineering Laboratory
to conduct dynamic tests on torque balanced wire and synthetic rope. The tests were
conducted at the laboratories of Preformed Line Products Company, Cleveland, Ohio.

The scope of the work was to provide data so that a basis can be established
to select the best type of line for load-handling purposes in the deep ocean environment.
The tests consisted of tension vs elongation, rotation and kink formation, and longitudinal
dynamic response.

The tension elongation tests yielded data typical to stranded line construction.

The rotation-kink tests revealed that negligible rotations resulted in the test
cables when under load and that no kinks were formed when the load was suddenly
released.

The dynamic response tests showed that the measured dynamic stresses were
dependent upon the exciting frequency. The natural frequency for the synthetic rope
sample was 0.3 cps and 0.6 cps for the wire rope.

The tests indicated that the highest values of combined static and dynamic stresses occur at resonance which could cause failure of the cable at points of high stress concentration.

It is recommended that some hydraulic parameters and random excitation be introduced in the future testing of this type. Stress relieving fittings should be investigated for use on load handling lines in the ocean environment.

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TEST REPORT

DYNAMIC TESTING OF LOAD HANDLING

WIRE ROPE AND SYNTHETIC ROPE (U)

NAVAL CIVIL ENGINEERING LABORATORY

N62399-69-C-0013

PROJECT NO. M9009-T

Introduction

The testing program described herein was conducted for the Naval Civil Engineering Laboratory, Contract No. N62399-69-C-0013, on government furnished steel wire rope and synthetic rope. The tests were conducted at the laboratories of Preformed Line Products Company, Cleveland, Ohio.

The objective of this work was to provide test data to be analyzed and evaluated as a basis for the selection of the best type of rope for load-handling purposes in the deep ocean environment. The types of tests conducted consisted of tension vs elongation, rotation and kink formation, and longitudinal dynamic response.

TENSION VS ELONGATION TEST

Description of Test Equipment

The equipment used to conduct the tension elongation tests was a horizontal testing machine with a loading capacity of 50,000 pounds and a span length of 66 feet. Fig. 1 is a schematic of the equipment.

The test machine has nonrotating clevis ends, one attached to a hydraulic ram and the other to an adjustable dead-end. The hydraulic system has a constant pressure pump with a flow control to vary the loading range. The load sensing system is composed of commercial load cells installed in series with electronic components and a 24-inch dial readout with varying load ranges up to 50,000 pounds.

Because of the substantial differences in the physical properties of the wire rope and the synthetic rope, the test setup was modified to suit the respective test samples. Since the strength of the wire rope exceeded the test machine loading capacity, a force-doubling pulley arrangement was applied between the machine ram and its frame and one end of the test sample. A 200,000-pound load cell was installed in series with the test sample to sense the load and a Baldwin SR-4 Strain Analyzer was employed to measure the tensile load in the test sample as shown in Fig. 2. Optical cathometers were used to measure the elongation. Fig. 3 shows the setup used.

The double pulley arrangement was not used for testing the synthetic rope, however, because of the stretch characteristics of the rope. The calculated elongation of the rope revealed that the machine ram travel was insufficient. Therefore, turn-buckles were used in line with the test sample to take up the initial stretch. Fig. 4 shows the test setup used. Elongation was measured with a steel tape to the nearest 1/8 inch.

Test Samples

All tests were performed using government furnished steel wire rope and synthetic rope. The wire rope was new. However, there was evidence that the synthetic rope had been in service prior to testing. The contractor was responsible for test sample terminations. The loops in the synthetic rope samples were formed by Samson Cordage, Boston, Massachusetts and the wire rope was terminated with spelter socket fittings. Specifications of the respective ropes are listed in Figs. 5 and 6.

Test Procedure

Each test sample was placed in the test machine and pulled taut to an initial tension of 1,000 pounds. A 60-inch gage length was then marked with an accuracy of ±1/16 inch.

Additional tensile load was then applied at the rate of 0.619 inches per minute in 5,000-pound increments. These incremental loads were held for one minute. During the load-holding periods, the corresponding elongations of the gage length were measured at the beginning and again at the end of the holding periods. The duplicate measurements were made in anticipation of possible human errors and for possible creep in the line material. Measurements were taken up to 60 per cent of the rated breaking strength of the material. The test samples were then pulled to destruction noting the approximate breaking load.

Test Results

Test results for the wire rope are tabulated in Tables I and II and shown in curve form in Fig. 7.

Test results for the synthetic rope are tabulated in Table III and shown in curve form in Fig. 8.

The ultimate fracture occurred at or near the terminating device for both types of material. Fig. 9 reveals that the wire rope failed at the edge of the zinc socket and Fig. 10 clearly shows the failure of the synthetic rope at the junction of the loop and the long end of the rope.

Discussion

The following problems were encountered during this series of tests.

The breaking strength of the wire rope exceeded the test machine capacity. A method to obtain higher loading was devised to utilize the existing test equipment.

The ram travel of the test machine was limited. A system and technique to take up the extensive stretch of synthetic rope had to be devised and employed.

Failures of the test samples below the rated breaking strength was a serious problem. In the case of the synthetic rope, the required elongation reading prior to failure was not measured because of the premature failure. This also caused concern for the safety of the laboratory personnel who were taking elongation readings. Nonrepeatability and deviation in measured data was evident.

In order to obtain confident elongation readings on the wire rope, several samples were tested. In the first samples, problems developed with the hydraulic system and the sample was cycled several times before it failed. The test sample was loaded to the capacity of the test machine and then the load was released and a pulley arrangement was installed. This technique resulted in a discontinuity and a hysteresis curve as shown in Fig. 11.

A second sample was tested. There was a strong deviation of data in this test and upon inspection of the test sample it was noted that at one socket fitting a strand had slipped out prematurely which could have caused the erratic readings. This data was discarded.

The most dependable data was obtained from the third sample tested and the data is presented in Fig. 7.

Additional samples of the synthetic rope were not tested because it was decided that the one test clearly indicated the weakness of the synthetic rope termination. To conduct further testing would have required additional time and expenditure to design, develop and manufacture a special end fitting to hold the full-rated strength of the synthetic rope.

For multistranded cable such as used in these tests, the attainment of full rated breaking strength depends a great deal upon the uniform loading of the individual strands. This is not a simple task when using most commercial fittings.

Due to intrinsic variations in the tensile and physical properties of a terminated cable, several test samples should be tested in order to yield enough data to determine an effective holding strength and a representative cable modulus of elasticity   Unfortunately, extra test samples were not available because of the limited amount of material on hand and for the economic reasons mentioned earlier.

ROTATION AND KINK FORMATION TESTS

Test Equipment and Setup

The laboratory was faced with the problem of testing relatively long lengths at various high loads in a vertical configuration. Existing laboratory equipment did not have the required amount of weight, the lifting capacity nor the needed heights. Therefore, it was decided to conduct the rotation and kink tests outdoors at a local scrap yard where the weights and a crane with lifting and height capacity were available.

Each test sample was vertically suspended from a boom having a locked clevis attachment at the top. The bottom end of the suspended test sample was loaded with attached weights and was free to rotate.

Four groups of preweighed weights were used for each test sample. Weights of 2,250, 4,500, 6,900, 9,000 pounds were used to test the synthetic rope samples, and 4,100, 7,800, 11,800, 15,400 pounds were used to test the wire rope samples.

A 36-inch machinist scale was suspended from an upper gage mark of each test sample to measure elongation.

Visual observations of the associated rotations were made by means of stationary and rotating markers, one on the ground and one on the attached weight assembly, respectively.

Test Samples

Eight test samples were prepared as follows:

Test Sample No. 1	19 feet	2 inches	Synthetic
Test Sample No. 2	10 feet	11 5/8 inches	Wire
Test Sample No. 3	19 feet	5/8 inch	Synthetic
Test Sample No. 4	10 feet	11 1/8 inches	Wire
Test Sample No. 5	18 feet	9 5/8 inches	Synthetic
Test Sample No. 6	10 feet	11 5/8 inches	Wire
Test Sample No. 7	17 feet	11 1/8 inches	Synthetic
Test Sample No. 8	11 feet	1 inch	Wire

The lengths for the wire rope were measured from mouth-to-mouth of the socket fitting. The lengths for the synthetic rope were measured from pin-to-pin.

Test Procedure

At the beginning of each test, the test samples were preloaded with a tare load of 200 pounds. At this time the initial nominal length was measured, the 120-inch gage length was marked, visual alignment of the end fittings was ascertained and a bench mark, or zero reading, for subsequent rotation was obtained.

The sample was then lowered and the required weights were attached to the test sample. Each loaded test sample was then raised off the ground. During the raising process, the weighted end was manually held by a technician in the zero position. The manual rotational restraint was then released and the assembly was allowed to rotate and oscillate freely. Observations of the direction and magnitude of the maximum rotations were made and recorded. When the oscillations stopped, the elongation position of the lower gage mark was measured and recorded. (Fig. 12)

The weighted assembly was then dropped to the ground by rapidly lowering the boom. The test sample was allowed to collapse several feet. Observations for kink formation were then made. Figs. 13 and 14 show the collapsed cable with no kinks.

Test Results

The results are tabulated in Tables IV and V. Graphs were not constructed because the observed angular rotations were comparatively small and inconsistent. An example of this inconsistency can be seen in Table V. During the outdoor testing of the synthetic rope, the sample rotated 225 degrees at a load of 4,500 pounds. At a load of 6,900 pounds, the sample rotated 45 degrees, and at 9,000 pounds, 135 degrees.

Discussion

Prior to testing, it was assumed that the constructionally torque-balanced test samples would tend to twist when loaded axially and that they would form characteristic kinks upon sudden release of the tensile load. The test results indicate otherwise, and all the tests showed comparatively little or no rotation and no kinks were formed. Because of the unexpected results, several repetitious tests were run. Also, a series of rechecks in the laboratory on the horizontal testing machine were conducted to compare with data obtained outdoors. In the laboratory the test samples were attached to a rotating clevis of thrust-bearing construction on one end to allow the sample freedom of rotation during loading. Despite some frictional resistance of the rotating clevis, these laboratory rechecks substantially corresponded with the outdoor results regarding the order of magnitude for the expected angular rotation. Again, these angular movements were very small in comparison with what might be expected from multistrand cable not having torque-balance design features.

These test results indicate that the manufacturer's claims to a torque-balanced line were virtually substantiated, at least for the lengths of the test samples employed. This does not imply that the test samples were free of torque conditions. The test results brought attention to the need for finite rotational measurements, when this data is required to extrapolate sample lengths to substantially longer lengths of torque-balanced cable.

The results of no kink formation indicated that the torque developed under load was negligible for these cable constructions, resulting in no rotation. Therefore, there was no cable distortion which would cause kinks in the cable, should a slack condition suddenly develop.

DYNAMIC RESPONSE

Considerations Prior to Testing

The laboratory was faced with numerous test-engineering problems prior to testing. These problems and their respective solutions are described as follows.

Interpretation of realistic sea-state periods corresponded to relatively low frequencies in tensile excitation which were coupled with relatively small cyclic specimen displacements.

In order to determine the modifications required to match our existing equipment capabilities with the test performance requirements as outlined, the basic dynamics of the test program were further analyzed. The N.C.E.L. Technical Report No. 433 (AD 631 267) was reviewed and the mathematical model was converted to a laboratory test model. Such efforts revealed the following:

1. Fundamental resonance can occur at relatively low frequencies for both rope materials, particularly when design parameters were scaled down to those of a laboratory test model. Calculations are included at the end of the text.

2. The magnitude of the cyclic axial displacements did not enter into the dynamic response of the taut-rope mass system.

3. The installation of another weight at the driving end of the test span, for the purpose of maintaining a nominal rope tension during the cyclic excitation, did not essentially affect the dynamic response, particularly at resonance.

Practical test equipment modifications, and a test procedure and setup were devised and employed. Such equipment was believed to provide valid simulation of the dynamics involved in a vertical ocean-lift system.

The equipment array, as shown in Figs. 15 and 16, was designed, fabricated and assembled for conducting this series of tests.

After some preliminary tests using the wire rope test sample (equipment and technique shake-down period), the dynamic forces at resonance indicated the need for substantial rope terminating fittings. This requirement became acute for the synthetic rope material, in light of the termination deficiency experienced with the loop termination during the previous tension elongation tests.

Because of this necessity, an encapsulated termination of the synthetic rope was developed and was cycled between 10,000 and 20,000 pounds (expected region under the dynamic test equipment) in the tensile testing machine without any slippage.

Test Samples

Both types of rope material were furnished by N.C.E.L. They were cut to length and equipped with terminating fittings. The length of the wire rope test sample was 116 feet 7 inches. The length of the synthetic rope test sample was 117 feet 3 inches. Both lengths were measured under a nominal tension of 10,000 pounds tension while resting in the test span.

The terminating fittings for the wire rope were identical to those described and shown in Fig. 9.

The terminating fittings for the synthetic rope were constructed as follows:

    a. The core and the outer layer strands were untwined and thoroughly wetted with Scotch-Cast No. 9 resin (3-M product).

    b. The outer-layer strands were circumferentially placed and wedged by a metallic core piece against the inside wall of the clevis-type socket fitting.

c. The core strands were fed through the large center hole of
the wedging cone piece. The extended core strands were
radially mushroomed outward.

d. The entire assembly was then potted with Scotch-Cast No. 9
resin, making particularly certain that sufficient resin was
present in the necked cavity of the fitting.

Test Equipment, Setup and Instrumentation

The test equipment, setup and instrumentation were common to both test
samples of wire and of synthetic rope. The overall arrangement is shown schematically
in Fig. 17. The constituents were as follows:

Abutments provided the supporting structure for the spanned test assembly.

Guides offered horizontal guidance at three different locations along
the span to minimize vibration to the test span.

Turnbuckles provided a means of fine adjustment in tensioning the
test samples to the desired nominal 10,000-pound line tension.
One clevis stud of each turnbuckle was instrumented with
strain gages to measure axial tensile load.

Pillow Blocks provided the longitudinal guidance for the actuating
linkages. These pillow blocks were constructed of Thomson
linear ball bearings, thus offering minimal sliding friction.

Loading Beams & Dead Weights provided load multipliers and the
maintenance of line tension. The driving beam end transmitted
the sinusoidal excitation. The pivoting beams were constructed
with antifriction ball bearings.

Load Cells were used to sense the tension variations at the input and
output ends. The safe working load for both load cells was
18,000 pounds.

Linear Variable Differential Transformers were used to measure the
longitudinal displacements.

Drive Mechanism provided the cyclic longitudinal displacements at
variable frequencies and amplitudes. The mechanism consisted
of a variable gear motor, sprocket-chain, jack-shaft reduction
stage, driving a variable crank-arm, four-slide mechanism.
The slider was attached to the pivoted beam through a pin-slot.

Instrumentation Recorder was a Honeywell No. 1020 multichannel
oscillograph. It was complemented with a Heiland oscillator
and carrier amplifiers. The recording galvos were of 1,600 cps
response.

Test Procedure

The test samples were installed between the abutments of one of the 125-foot
vibration beds. In order to arrive at the correct final installed test sample lengths
between the end abutments required a predetermination of the load-free length of
the test sample.

For the wire rope, theoretical calculations of the required length were rather
straightforward. However, for the synthetic rope, predetermination of the length was
not so easily accomplished. The theoretical calculations of the stretch only provided
a regional length. The exact length dimension was difficult to determine because of
the various inaccuracies of the physical data used to calculate the stretch length when
under load. One of these factors was looseness of the external layer of the synthetic
rope. Therefore, a trial and error method was used. That is, a length of rope was
installed and the length under load was noted. The sample was then removed and
shortened and then reterminated. The final load-free length resulted in a much shorter
length than the calculations indicated. The test samples were pulled into position by
using ratchet type line hoists. The test samples were then secured in the test span when
the inline load reached 10,000 pounds for the wire rope and 13,000 pounds for the
synthetic rope. When the pulling end device was removed, the span line tension dropped
to somewhat below the required test load.

The final nominal tensioning to test load was accomplished by adjusting the
turnbuckles which were installed in series with the test samples. After acquiring
the desired test tension, the guides were attached to eliminate transverse vibration
of the test samples.

The required instrumentation used to sense the predetermined test parameters
was then installed and calibrated. This instrumentation consisted of two LVDT's to
measure the displacement at either end and two load cells to measure the force
variations at the input and output end. During the running of the test all the force
and displacement signals were simultaneously recorded on the oscillograph.

To reach the low natural frequency of the tested taut-rope mass system, the
driver mechanism was started at a speed above resonance, then incrementally swept
upward about 5 cps and swept downward until the resonant frequency was reached.
At resonance, the driven end of the wire rope displayed significantly large amplitudes
of displacement.

In the case of the synthetic rope, resonance was not obtainable from the
machine drive because its lowest geared downspeed was not low enough to approach
the natural frequency of the system. The method used to obtain the natural frequency
was to rap the driven beam at the rate of about two or three times a second until an
apparent and sustaining resonance resulted.

In each test, simultaneous oscillographic recordings of the four sensors were taken at incremental excited frequencies with two or three different longitudinal displacement amplitudes. After completing the dynamic test, the setups were disassembled and the individual moving parts were weighed. A list of these weights is presented in Table XVII, so that correlations with the associated analytics can be accomplished.

Test Results

Test results for the wire rope are tabulated in Tables VI through X and shown in curve form in Fig. 18.

Test results for the synthetic rope are tabulated in Tables XI through XVI and shown in curve form in Fig. 19.

A typical recording of the dynamic response data is presented in Fig. 20.

These tests clearly indicated that the dynamic amplitudes and stress in the rope were dependent upon the exciting input frequency. This dependence can be more specifically related to the ratio of the exciting frequency and the natural frequency for a given taut-rope mass system. Although maximum dynamic amplitudes were always obtained at resonance, maintaining resonance was observed to be very difficult because the resonance frequencies peaked over sharply and the delineation between resonant and nonresonant states was quite abrupt. Consequently, most of the test results were obtained under nonresonant conditions. At these conditions, the driven end was virtually at a standstill. This indicated that the input-exciting displacements caused elastic elongations in the test samples.

Since the synthetic rope has a lower spring constant and associated dampening, it had to be excited with larger longitudinal displacements than the wire rope in order to yield readable data.

Discussion

Selection of the frequency spectrum

The taut rope-mass arrangement of this experimentation could be compared to a spring-mass system with the support being sinusoidally excited. The natural frequency of such a simplified system is dependent upon the effective spring constant and the suspended mass.

In relating laboratory testing to a specific oceanographic application, the k/m expression can vary widely. Such large variations can be caused by the rope material, its length and the "virtual" mass of the submerged constituents. The laboratory experiments indicated the rope material and length appeared to be the most effective parameters. Since the effective spring constant, k, varies

inversely with the length of a line, relatively low natural frequencies would be expected. In this regard, the experimental setup simulated a considerably longer rope length than the test sample due to the modifying dynamic effect of the lever arm ratio, a/l, for the pivoting beam.

The employment of relatively low test frequencies can be further supported by laboratory test efforts in attempting to obtain and observe maximum dynamic stresses in the cable. Maximum dynamic stresses are most easily obtained at fundamental resonance; that is when the frequency of the exciting source equals the fundamental frequency of the taut rope system. In reference to sea applications, the heaving movement of a ship is characterized by low frequencies.

Therefore, when the above aspects are combined, the selection of the reported test frequency spectrum (0.3 to 5.0 cps) appears to be in order with realistic line parameters and with the expected excitations at sea.

Maximum stress

Measurements of the dynamic stresses indicated they can be of significant magnitude occurring almost simultaneously and of equal magnitude at both ends in the relatively short laboratory test samples. Consequently, fatigue may become a serious concern for an actual sea application.

The most likely occurrence of incipient fatigue may be at or near the ship end, because at that location the state of combined stresses is the most severe. In contrast, the magnitude of the combined stresses decreases with increasing depth along a nonbuoyant line due to diminishing line weight. However, high local stress concentration can result from attaching to the cable some fittings and appendages which do not have stress-relieving design features. These conditions can cause an early failure of the cable. In such cases, failure usually occurs where these fittings are located along the submerged line.

Combined stress

A load-handling rope in the ocean can be, and usually is, subjected to a combination of static and dynamic stresses which can exceed the critical stress of the rope material and cause failure. These stresses are usually axial, torsional, flexural and radial compressive and are generally identifiable. However, radial compressive stresses are not easily defined and do not lend themselves to analytical solutions. For example, in the case where two layers of individual wires are stranded in opposite lay direction, as in double-armored

cable, there is point-to-point contact between the two layers and any radial compressive stresses, such as passage over a sheave or the attachment of any bolted hardware to the line, will contribute to the high levels of localized stress concentration.*

The need for endurance information under combined stresses and wet conditions have become apparent. Such data would provide an ultimate meaning to field and laboratory determinations.

Elongations

During the past it was observed that at resonance the elastic elongations of the rope were toward the driven or output end. During nonresonance the elongation took place in the opposite direction, toward the input or simulated ship end. This can be observed from Fig. 19, and by noting the dynamic response Tables VI through XVI. Referring to Fig. 19, at resonant frequencies the output-input ratio is relatively high compared to the nonfrequency ratios.

For example, from Fig. 19 and Table VII, at a frequency of .60 cps the input displacement is 90 mils and the output displacement is 700 mils. The ratio is 7.78. However, at a nonresonant frequency of 1.5 cps and higher, the ratio tends to become flat but at a much lower value of .040 at 3.00 cps.

Relating these observations to a combined construction of wire and synthetic ropes, then substantially all the dynamic elongations would occur in the synthetic rope whether at resonance or at nonresonance.

Problems encountered

Some experimental problem areas may be outlined as:

1. A comprehensive test engineering analysis was necessitated prior to the design of the experimental equipment.

2. The appropriateness, limitations and modifications of the existing facilities had to be thoroughly explored.

3. The need for a suitable, dynamic terminating fitting for the synthetic rope was required and had to be constructed so as to insure successful completion of the test program.

* J. C. Poffenberger, E. A. Capadona, and R. B. Sitter, "Dynamic testing of cables," Transactions, 2nd Annual Marine Technology Society Conference, Washington, D. C., Exploiting the ocean, pp 485-523. June 27 - 29, 1966.

Summary

The laboratory experiments indicated the rope material and length appeared to be the parameters which most affected the k/m expression. The tests also confirmed the relatively low natural frequencies which were expected in the considerable longer rope lengths used in the ocean.

The laboratory tests also indicated that the maximum dynamic stresses usually occur at fundamental resonant frequencies of the rope system. Measurements of these dynamic stresses showed that they can be of significant magnitude occurring simultaneously at both ends of the relatively short laboratory samples. A study of Fig. 20 and the dynamic response tables indicate this situation and also reveal that at resonance the elastic elongations of the rope are toward the driven or output end. During nonresonance, the elongation takes place in the opposite direction, toward the simulated ship end.

RECOMMENDATIONS

1. Closer simulation of the sea application may be obtained by introducing some of the hydraulic parameters, viz., drag, buoyancy.

2. Random loading of test samples should be investigated. Under random loading conditions, low frequency resonance becomes difficult to sustain because the resonant frequencies peaked very sharply and the delineation between resonant and nonresonant state was abrupt.

3. Endurance data for various rope material is needed and is of great importance in the sea environment. The needed endurance data could be categorized as a high state of stress combined with a low cycle life, and a low state of stress combined with high cycle life.

4. Terminating fittings should be carefully selected in conjunction with the associated dynamics since the weakest link in some systems is at or near the termination.

5. A reliable terminating device should be designed and employed, in order to establish an adequate basis for comparison and selection of the best type of line for load-handling purposes. Then, a relatively large number of samples should be tested. Testing of several samples is desirable for any material. This desirability becomes especially acute for stranded line materials which are inherently characterized by nonuniformity of loading along the individual strands and/or among their groupings.

6. More sophisticated instrumentation should be developed to obtain vernier rotation measurements which could become useful, so that the amount of rotation from relatively short length laboratory samples could be extrapolated to longer field lengths. If loops had been formed and kinks developed on short lengths in the laboratory, then it could be safely assummed that loops and kinks will form on very long lengths.

7. It is recommended that the rotation kink formation phase of testing be further investigated from the standpoint of determining how much rotation is actually needed to form a loop and a kink.

ACKNOWLEDGEMENTS

:jmc

TABLE 1

TENSION ELONGATION DATA FOR WIRE ROPE SAMPLE NO. 1 *

Gage Length — 60 inches

1st Loading Cycle		Unloading Cycle		2nd Loading Cycle**	
Load	Elongation	Load	Elongation	Load	Elongation
(lbs)	(ins)	(lbs)	(ins)	(lbs)	(ins)
1,000	.000	50,000	.306	10,000	.000
5,000	.047	45,000	.341	20,000	.056
10,000	.084	40,000	.298	30,000	.100
15,000	.123	35,000	.254	40,000	.146
20,000	.132	30,000	.228	50,000	.236
25,000	.170	25,000	.190	55,000	.242
30,000	.202	20,000	.152	60,000	.307
35,000	.204	15,000	.142	65,000	.329
40,000	.232	10,000	.105		
45,000	.263	5,000	.055		
50,000	.306	1,000	.029		

* See Hysteresis Curve Fig. 11.

** Force multiplying pulley arrangement was installed to obtain higher loadings.

TABLE II

TENSION ELONGATION DATA FOR WIRE ROPE SAMPLE NO. 3

Gage Length — 60 inches

Load (lbs)	Elongation (ins)
1,000	.000
5,000	.103
10,000	.152
15,000	.184
20,000	.224
25,000	.260
30,000	.296
35,000	.335
40,000	.366
45,000	.410
50,000	.433
55,000	.494
60,000	.528

Wire rope failed at 66,500 pounds.

TABLE III

TENSION ELONGATION DATA FOR SYNTHETIC ROPE SAMPLE NO. 1

Gage Length — 60 inches

Load (lbs)	Elongation (ins)
1,000	0.00
2,000	0.50
5,000	2.00
10,000	4.31
15,000	6.50
20,000	8.44
25,000	10.63

Synthetic rope failed at 29,200 pounds.

TABLE IV

ROTATION AND ELONGATION DATA FOR WIRE ROPE

(Outdoor Measurements)

Load	Specimen No.	Elongation	Rotation
(lbs)		(ins)	(degrees)
200		0	0
4,100	2	6/64	0
7,800	4	7/64	45
11,800	6	14/64	90
15,400	8	12/64	135

(Laboratory Measurements)

Load	Specimen No.	Elongation	Rotation
(lbs)		(ins)	(degrees)
200		0	0
4,100	2	5/64	20
7,800	4	10/64	5
11,800	6	13/64	9
15,400	8	17/64	4

TABLE V

ROTATION AND ELONGATION DATA FOR SYNTHETIC ROPE

(Outdoor Measurements)

Load (lbs)	Specimen No.	Elongation (ins)	Rotation (degrees)
200		0	0
2,250	1	4 11/64	0
4,500	3	7 32/64	225
6,900	7	9 43/64	45
9,000	5	10 56/64	135

TABLE VI

STEEL WIRE ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 60 Mil Peak-to-Peak

Frequency (cps)	Force Input (Fi) (lbs)	Force Output (Fo) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	Fi/ΔT	Δo/ΔT	Remarks
							Line Tension: 10,250 lbs
0.55	850	600	60	185	1.335	3.09	Attn. Used
0.55	800	750	60	180	1.335	3.00	LVDT -1
1.00	350	300	60	15	.583	.25	Load Cell -2
1.00	350	300	55	15	.637	.25	
1.10	400	300	60	15	.667	.25	
1.40	300	250	60	0	.500	.00	
1.66	350	300	60	5	.583	.25	
1.66	350	300	60	5	.583	.25	
1.66	300	250	60	5	.500	.25	
1.70	350	250	60	0	.583	.00	
2.00	350	220	60	0	.583	.00	
2.25	350	300	65	0	.538	.00	
2.25	350	300	65	0	.538	.00	
3.33	350	300	60	0	.583	.00	
3.50	350	300	60	0	.583	.00	
2.50	350	300	65	0	.538	.00	
2.50	350	250	65	0	.538	.00	
2.66	350	300	60	0	.583	.00	
2.66	350	300	60	0	.583	.00	
3.00	350	300	60	0	.583	.00	
3.00	350	300	60	0	.583	.00	

TABLE VI (continued)

STEEL WIRE ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 60 Mil Peak-to-Peak

Frequency	Force Input (F_i)	Force Output (F_o)	Displacement Input (Δi)	Displacement Output (Δo)	$\dfrac{F_i}{\Delta i}$	$\dfrac{\Delta o}{\Delta i}$	Remarks
(cps)	(lbs)	(lbs)	(mil)	(mil)			
3.10	350	300	65	0	.538	.00	
3.16	350	300	70	0	.500	.00	
3.25	400	350	70	0	.572	.00	
3.50	350	350	70	0	.500	.00	
3.86	400	350	70	0	.572	.00	
4.00	400	350	70	0	.572	.00	

TABLE VII

WIRE ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 120 Mil Peak-to-Peak

Frequency (cps)	Force Input (Fi) (lbs)	Force Output (Fo) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	$\frac{Fi}{\Delta i}$	$\frac{\Delta o}{\Delta i}$
0.55	1,500	1,500	140	550	1.070	3.9300
0.58	4,700	4,400	150	990	3.130	6.6000
0.60	4,450	4,050	145	925	3.070	7.7200
0.60	3,250	3,900	90	700	3.610	7.7800
0.66	5,200	4,700	140	1,030	3.720	6.8700
0.85	1,500	1,300	120	135	1.250	1.1300
1.00	1,000	800	125	45	.800	.3590
1.00	1,000	900	120	70	.833	.5830
1.10	1,000	800	125	40	.800	.3200
1.40	800	700	125	20	.638	.1600
1.40	750	700	125	20	.600	.1600
1.50	800	700	125	20	.640	.1600
1.55	800	700	125	15	.638	.1200
1.55	750	600	125	15	.625	.1200
1.65	750	600	125	15	.625	.1200
1.75	750	600	125	15	.625	.1200
1.75	750	650	120	15	.625	.1250
2.00	700	600	120	5	.583	.0400
2.00	800	700	130	10	.615	.0768
2.00	700	600	130	10	.538	.0770
2.30	700	550	125	5	.560	.0400

Remarks

Line Tension: 10,600 lbs

Calibration

LVDT

Attn.	Mil/Div
0.1	20
0.2	10

Load Cells

Attn.	µ∈/Div	Cell No. M900°	Cell No. 68087
0.1	40	368 #/Div	466 #/Div
0.2	20	184 #/Div	233 #/Div
0.5	8	74 #/Div	94 #/Div
1.0	4	37 #/Div	47 #/Div

Attn. Used
LVDT   0.1
Load Cells 0.1

TABLE VII (continued)

WIRE ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 120 Mil Peak-to-Peak

Frequency	Force Input (Fi)	Force Output (Fo)	Displacement Input (Δi)	Displacement Output (Δo)	$\frac{Fi}{\Delta i}$	$\frac{\Delta o}{\Delta i}$	Remarks
(cps)	(lbs)	(lbs)	(mil)	(mil)			
2.50	700	600	125	5	.560	.0400	
2.50	800	700	125	5	.638	.0400	
2.60	700	650	135	5	.518	.0370	
2.70	800	750	125	5	.638	.0400	
2.85	700	600	140	5	.500	.0357	
3.00	750	600	125	5	.600	.0400	
3.00	800	700	130	5	.616	.0400	
3.20	750	700	125	5	.600	.0400	
3.30	700	650	140	5	.500	.0537	
3.50	700	700	130	5	.538	.0400	
3.50	750	700	125	0	.600	.0000	
3.80	700	700	145	0	.483	.0000	
3.90	750	800	135	0	.556	.0000	
4.00	800	700	135	0	.593	.0000	
4.00	750	700	140	0	.536	.0000	
4.00	700	700	145	0	.483	.0000	

TABLE VIII

WIRE ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 120 Mil Peak-to-Peak

Frequency	Force Input (Fi)	Force Output (Fc)	Displacement Input (Δi)	Displacement Output (Δo)	$\dfrac{Fi}{\Delta i}$	$\dfrac{\Delta o}{\Delta i}$	Remarks
(cps)	(lbs)	(lbs)	(mil)	(mil)			Line Tension: 10,000 lbs
1.00	1,100	980	123	45	.994	.3660	Attn. Used
1.00	1,128	980	125	50	.913	.4000	LVDT .2
1.50	940	832	126	20	.746	.1590	Load Cell .5
1.50	940	814	125	15	.746	.1200	
2.00	893	777	128	7	.697	.0547	
2.00	893	777	127	7	.697	.0540	
2.50	870	750	128	4	.680	.0540	
2.50	893	777	135	5	.662	.0540	
3.00	870	795	135	2	.644	.0150	
3.00	893	795	136	2	.657	.0150	
3.50	870	810	138	1	.632	.0070	
3.50	893	795	139	1	.644	.0070	
4.00	893	832	144	0	.620	.0000	

TABLE IX

WIRE ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 130 Mil Peak-to-Peak

Frequency (cps)	Force Input (Fi) (lbs)	Force Output (Fo) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	$\dfrac{Fi}{\Delta i}$	$\dfrac{\Delta o}{\Delta i}$	Remarks
0.40	282	259	133	155	.212	1.965	Line Tension: 10,000 lbs
0.50	638	592	135	210	.488	1.550	
0.55	3,854	3,404	145	725	3.650	5.000	Attn. Used
0.59	4,394	3,922	150	830	2.930	5.530	LVDT .2
0.62	4,606	4,070	150	850	3.070	5.660	Load Cells .5
0.82	1,540	1,387	125	130	1.230	1.040	
0.83	1,551	1,387	125	65	1.240	.520	At .59 cps South LVDT Attn. changed
0.90	1,269	1,110	125	80	1.015	.640	to .1.
1.00	1,104	980	125	55	.884	.440	All others remained the same.
1.10	1,034	888	125	40	.827	.320	
1.10	1,081	943	125	45	.865	.360	

TABLE X

WIRE ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 130 Mil Peak-to-Peak

Frequency (cps)	Force Input (Fi) (lbs)	Force Output (Fo) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	$\frac{Fi}{\Delta i}$	$\frac{\Delta o}{\Delta i}$	Remarks
.425	329	277	125	160	.263	1.280	Line Tension: 10,000 lbs
.526	1,081	962	130	285	.830	2.190	Attn. Used
.570	3,760	3,330	140	720	2.690	5.140	LVDT South .1
.600	4,277	3,737	145	805	2.950	5.560	North .2
.690	4,794	4,292	138	860	3.470	6.230	Load Cells .5
.833	2,514	2,590	125	360	2.330	2.880	
.833	1,622	1,443	120	140	1.350	1.170	
1.000	1,128	980	120	55	.940	.457	
1.050	1,034	925	120	50	.860	.417	
1.080	1,034	906	120	45	.860	.375	

TABLE XI

SYNTHETIC ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 120 Mil Peak-to-Peak

Frequency (cps)	Force Input (Fi)* (lbs)	Force Output (Fo)* (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo)* (mil)	$\frac{Fi}{\Delta i}$	$\frac{\Delta o}{\Delta i}$	Remarks
0.5	0	0	120	0			Line Tension: 11,300 lbs
1.0	0	0	120	0			
1.5	0	0	128	0			Attn. Used
2.0	0	0	135	0			LVDT .1
2.5	0	0	128	0			Load Cells .1
3.0	0	0	130	0			
3.5	0	0	130	0			
4.0	0	0	130	0			

* The force and displacement readings were below the resolution of the instrumentation. Therefore, these readings were tabulated as zero.

TABLE XII

SYNTHETIC ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 200 Mil Peak-to-Peak

Frequency	Force Input (Fi)	Force Output (Fo)	Displacement Input (Δi)	Displacement Output (Δo)	$\frac{Fi}{\Delta i}$	$\frac{\Delta o}{\Delta i}$	Remarks
(cps)	(lbs)	(lbs)	(mil)	(mil)			Line Tension: 11,000 lbs
.40	94	92	190	0	.0495	.00	Attn. Used
.50	94	74	190	0	.0495	.00	LVDT .2
.55	94	74	190	0	.0495	.00	Load Cells .5
.60	94	74	195	0	.0483	.00	
.63	94	74	195	0	.0483	.00	
.63	94	74	195	0	.0483	.00	
.63	94	74	195	0	.0483	.00	
.63	94	74	195	0	.0483	.00	
.63	94	74	195	0	.0483	.00	
.89	94	74	195	0	.0483	.00	
.99	94	74	195	0	.0483	.00	
1.00	94	74	195	0	.0483	.00	
1.50	94	74	195	0	.0483	.00	
2.00	94	74	197	0	.0477	.00	
2.50	94	74	197	0	.0477	.00	
3.00	94	74	197	0	.0477	.00	
3.50	94	74	200	0	.0470	.00	
3.70	94	74	197	0	.0477	.00	

TABLE XIII

SYNTHETIC ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 200 Mil Peak-to-Peak

Frequency (cps)	Force Input (F_i) (lbs)	Force Output (F_o) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	$\dfrac{F_i}{\Delta i}$	$\dfrac{\Delta o}{\Delta i}$	Remarks
.40	94	74	197	0	.0477	.00	Line Tension: 11,000 lbs
.45	94	74	197	0	.0477	.00	
.50	94	74	197	0	.0477	.00	Attn. Used
.55	94	74	197	0	.0477	.00	LVDT .2
.60	94	74	197	0	.0477	.00	Load Cell .5
.67	94	74	197	0	.0477	.00	
.69	94	74	197	0	.0477	.00	
.97	94	74	197	0	.0477	.00	
1.00	94	74	197	0	.0477	.00	
1.50	94	74	200	0	.0470	.00	
2.00	94	74	205	0	.0457	.00	
2.50	94	74	205	0	.0457	.00	
3.00	94	74	210	0	.0447	.00	
3.50	94	74	210	0	.0447	.00	
3.80	94	74	215	0	.0437	.00	

TABLE XIV

SYNTHETIC ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 300 Mil Peak-to-Peak

Frequency (cps)	Force Input (Fi) (lbs)	Force Output (Fo) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	$\frac{Fi}{\Delta i}$	$\frac{\Delta o}{\Delta i}$	Remarks
.40	141	???	300	65	.0470	.217	Line Tension: 11,000 lbs
.43	141	???	300	50	.0470	.166	
.47	141	???	300	37	.0470	.123	Attn. Used
.56	141	???	300	20	.0470	.066	LVDT .2
.60	141	???	300	20	.0470	.066	Load Cells .5
.62	141	???	305	15	.0463	.050	
.62	141	???	305	15	.0463	.050	
.63	141	???	305	15	.0463	.050	
.63	141	???	305	15	.0463	.050	
.94	141	???	305	5	.0463	.015	
1.00	141	???	305	5	.0463	.015	
1.50	141	???	305	3	.0463	.010	
2.00	141	???	310	2	.0454	.006	
2.50	141	???	317	1	.0444	.003	
3.00	141	???	325	0	.0434	.000	
3.50	141	???	330	0	.0427	.000	

TABLE XV

SYNTHETIC ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 300 Mil Peak-to-Peak

Frequency (cps)	Force Input (Fi) (lbs)	Force Output (Fo) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	$\frac{Fi}{\Delta i}$	$\frac{\Delta o}{\Delta i}$	Remarks
.40	117	92	300	0	.0390	.00	Line Tension: 11,000 lbs
.54	141	92	300	0	.0470	.00	
.70	141	92	305	0	.0470	.00	Attn. Used
.90	141	92	305	0	.0470	.00	LVDT .2
1.00	141	92	305	0	.0470	.00	Load Cell .5
1.50	141	92	310	0	.0455	.00	
2.00	141	92	315	0	.0447	.00	
2.50	141	92	325	0	.0434	.00	
3.00	141	92	330	0	.0427	.00	
3.50	141	92	335	0	.0422	.00	

TABLE XVI

SYNTHETIC ROPE DYNAMIC RESPONSE DATA

Excitation Displacement: 480 Mil Peak-to-Peak

Frequency (cps)	Force Input (FI) (lbs)	Force Output (Fo) (lbs)	Displacement Input (Δi) (mil)	Displacement Output (Δo) (mil)	$\frac{FI}{\Delta i}$	$\frac{\Delta o}{\Delta i}$	Remarks
0.38	282	185	455	165	.0620	.3630	Line Tension: 11,000 lbs
0.44	235	166	455	95	.0494	.2090	
0.46	235	148	455	77	.0494	.1700	Attn. Used
0.55	235	148	435	45	.0494	.1000	LVDT South .2
0.64	235	148	455	27	.0494	.0600	North .1
0.73	235	148	455	20	.0494	.0440	Load Cells .5
0.85	235	148	460	15	.0488	.0327	
0.93	235	148	460	10	.0488	.0218	
0.99	235	148	460	10	.0488	.0218	
1.00	235	148	460	7	.0488	.0153	

TABLE XVII

WEIGHTS OF INDIVIDUAL MOVING COMPONENTS USED IN
DYNAMIC RESPONSE TESTS

Driving End

Weight and Basket	670 lbs	6 oz
Beam and Clevis	73 lbs	7 oz
Pillow Block Shaft	11 lbs	15 oz
LVDT Actuator Core	2 lbs	0 oz
Turnbuckle Assembly	21 lbs	3 oz

Driven End

Weight and Basket	1,127 lbs	5 oz
Beam & Clevis	76 lbs	3 oz
Pillow Block Shaft	11 lbs	11 oz
LVDT Actuator Core	3 lbs	14 oz
Turnbuckle Assembly	21 lbs	12 oz
Wire Rope Test Sample with Fittings	171 lbs	7 oz
Synthetic Rope Test Sample Fittings	69 lbs	8 oz

CONTROL CONSOLE
AND FORCE READOUT

HYDRAULIC
CYLINDER

LOAD CELL

TEST SAMPLE
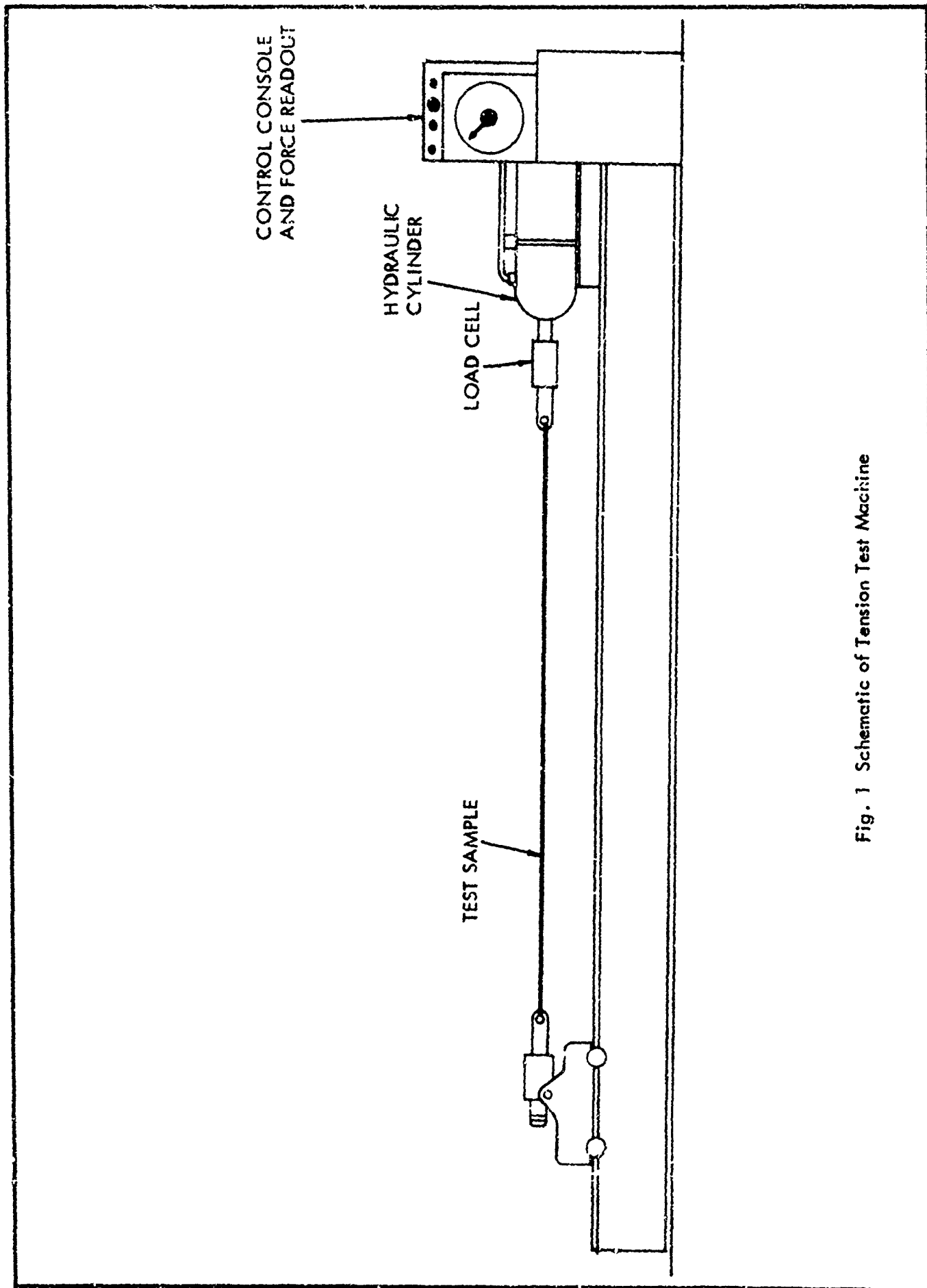
Fig. 1 Schematic of Tension Test Machine
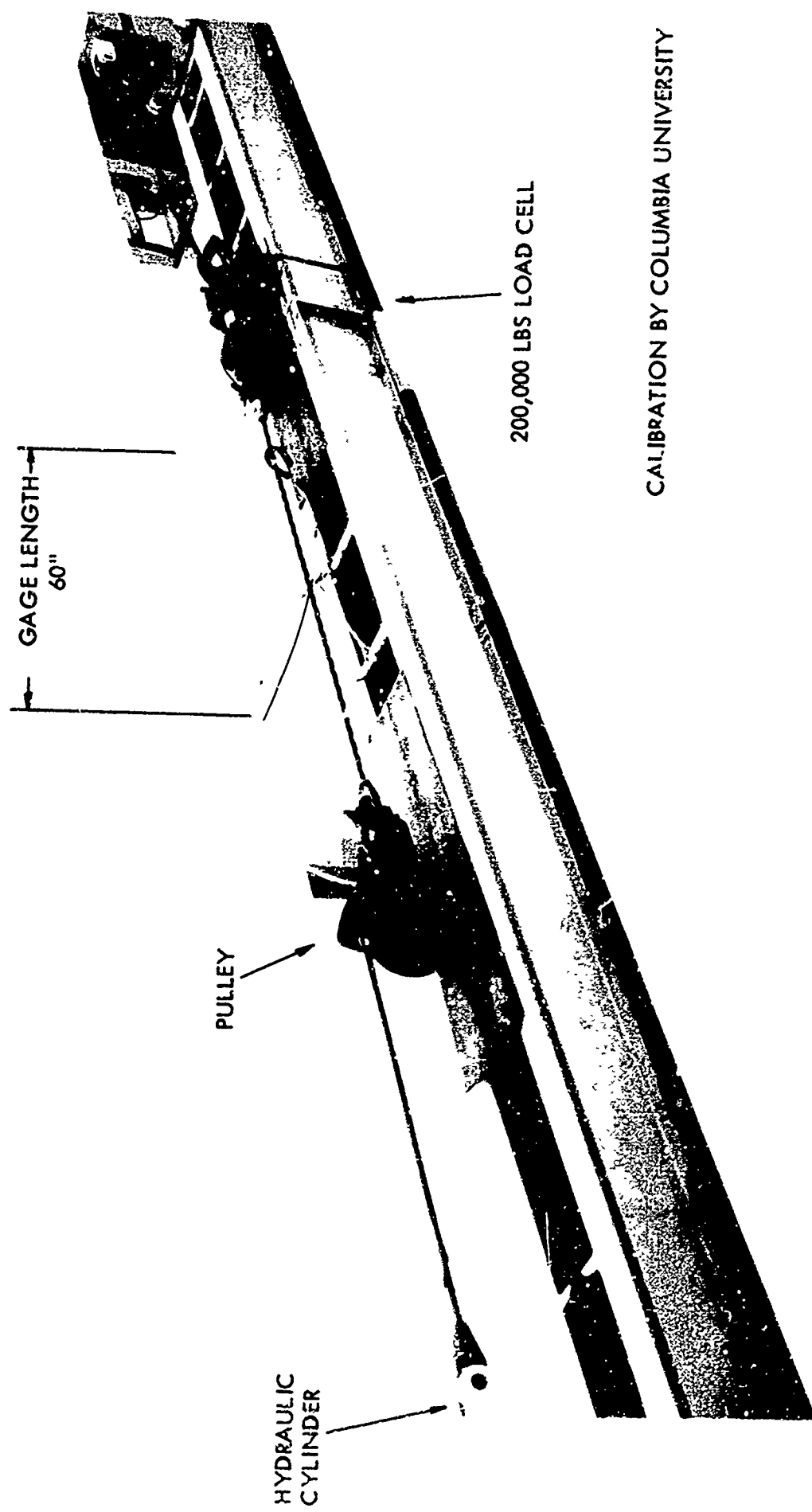
Fig. 2 Tension Test Setup for Wire Rope Using Force Doubling Pulley Arrangement
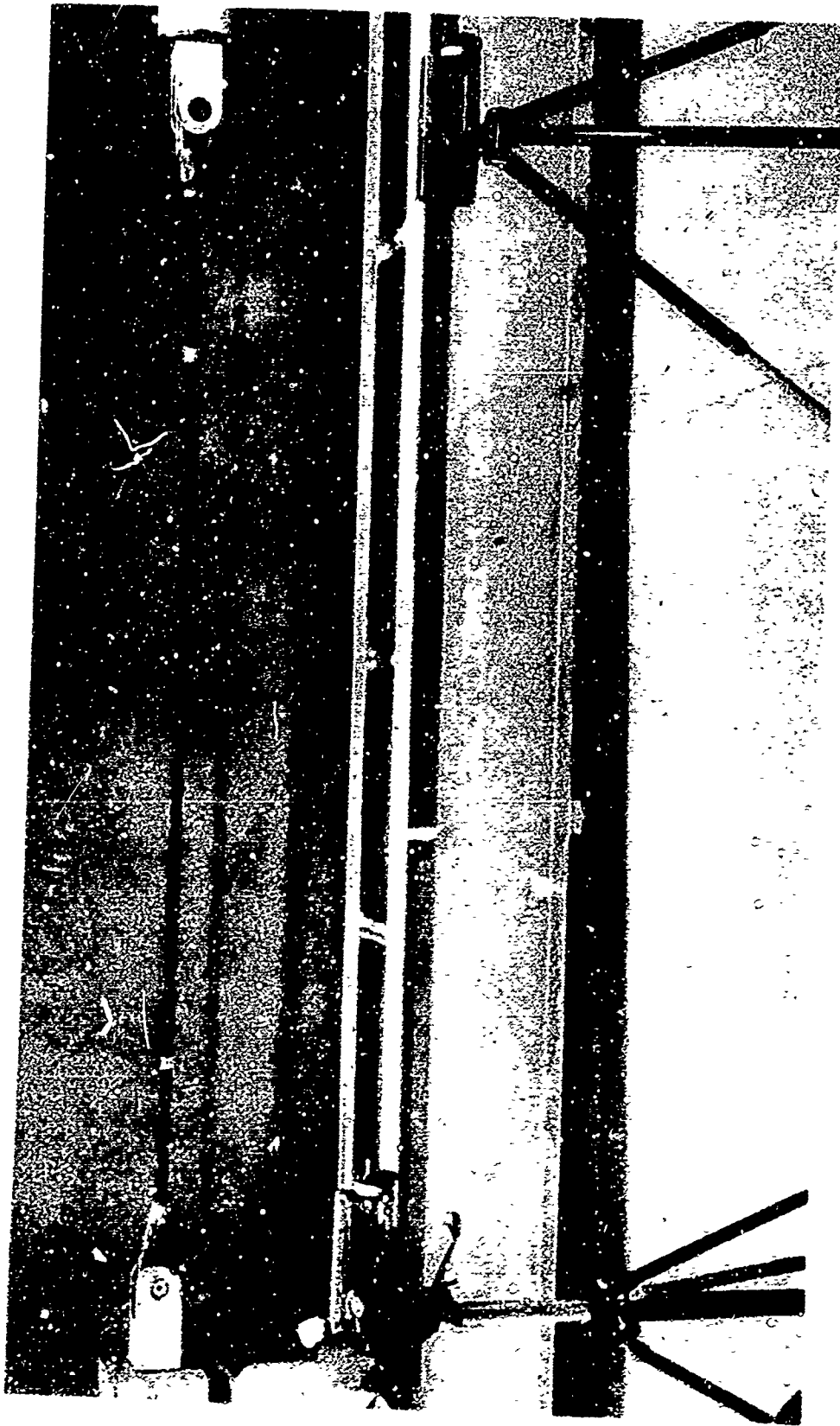
Fig. 3 Typical use of Cathometers to Measure Elongation. The Actual Test Setup is Shown in Fig. 2.

CONTROL AND FORCE
READOUT CONSOLE

SYNTHETIC ROPE

TURNBUCKLES
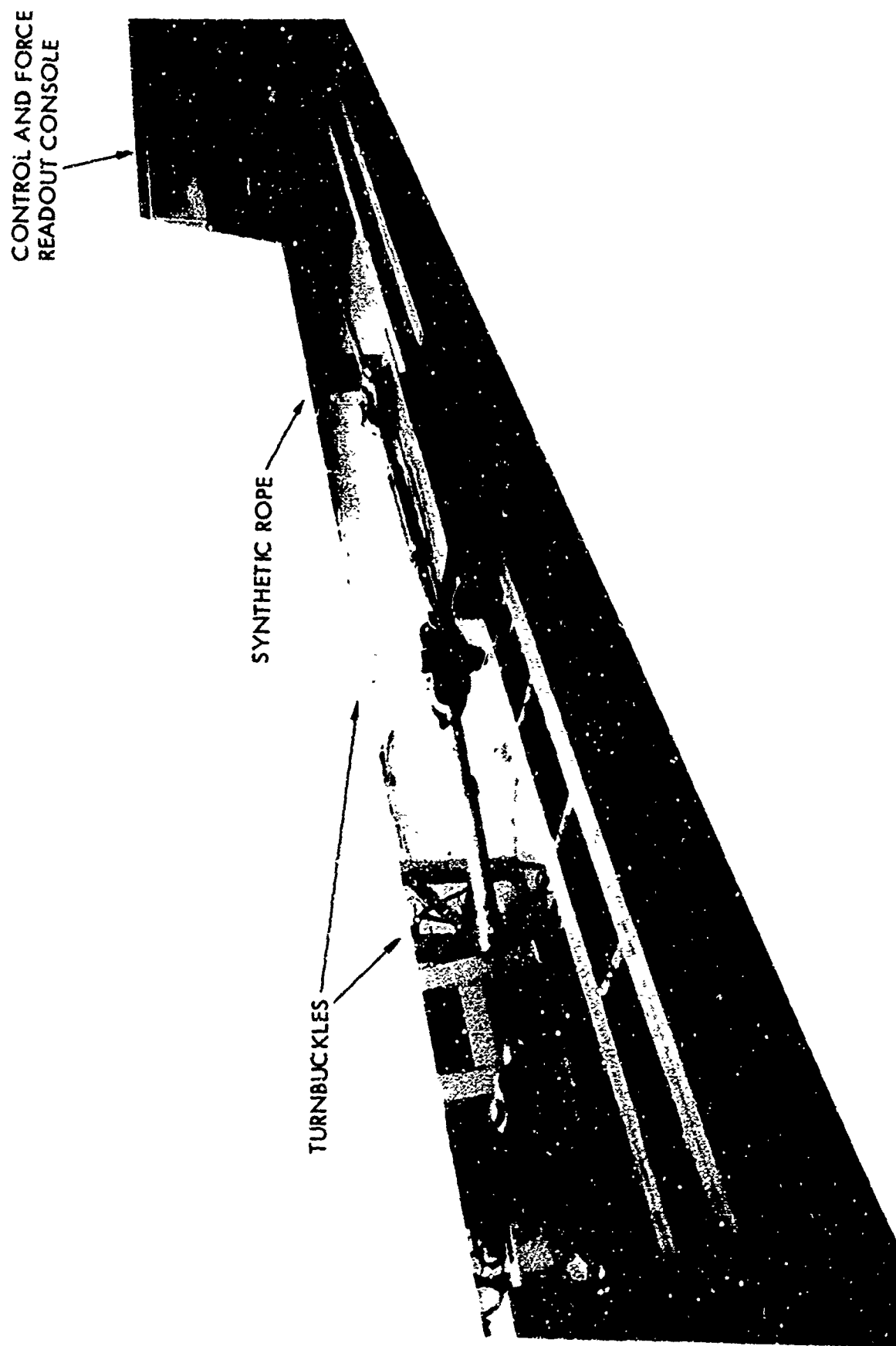
Fig. 4 Tension Test Setup for the Synthetic Rope Samples

7/8" DIA.
3 x 46 SCALE FW MONITOR AA WIRE ROPE (U.S. STEEL) BRIGHT, HEAVILY LUBED, PRESTRESSED, TORQUE-BALANCED

RBS: 78,000 LBS

WEIGHT: 1.27 LBS/FT

U. S. STEEL NEW PRODUCT

60"

GAGE LENGTH

12"

12"
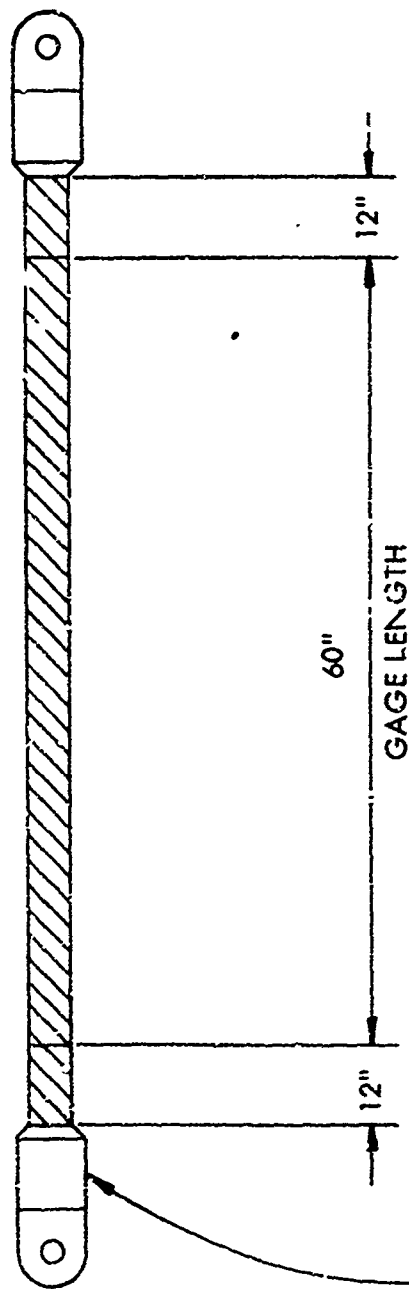
SOCKET FITTING

CROSBY LAUGHLIN
DIVISION AMERICAN HOIST
MODEL S417 7/8" DIA.
CLOSED SPELTER SOCKET

Fig. 5 Drawing of Typical Wire Rope Test Sample

60"

GAGE LENGTH

171" APPROX.

INSIDE CORE DISCONTINUED HERE
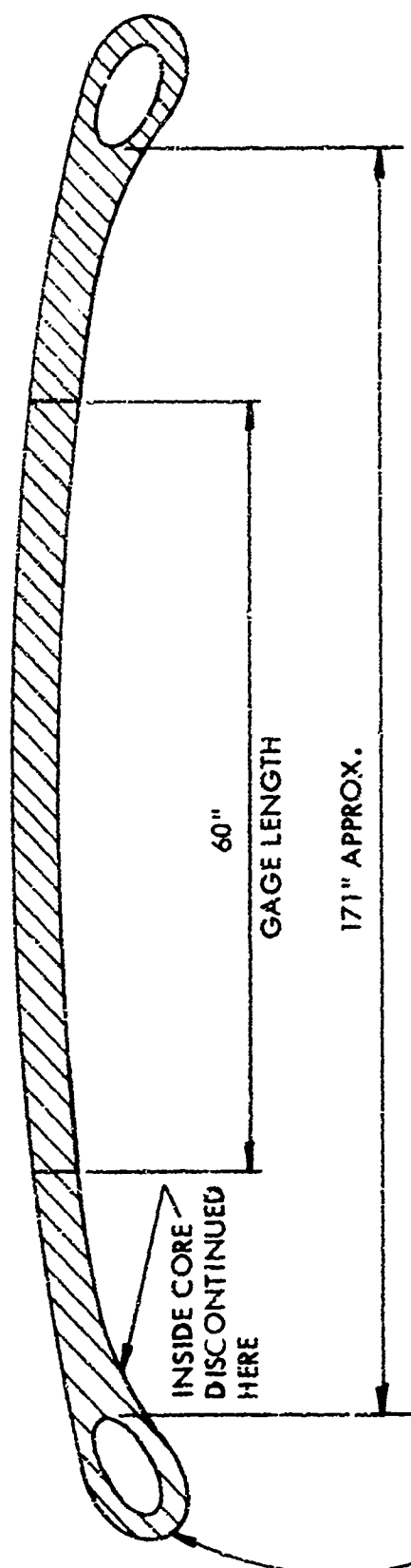
LOOPS WERE FORMED AND BRAIDED
BY SAMSON CORDAGE, BOSTON, MASS.

1 5/16" DIA., 4" CIRCUMFERENCE
SYNTHETIC ROPE, 2 IN 1 CONSTRUCTION
POLYPROPYLENE MULTIFILAMENT CORE
BRAIDED NYLON JACKET

RBS: 45,000 LBS

WEIGHT: 45 LBS/100 FT

SAMSON "POWER BRAID"

Fig. 6 Drawing of Typical Synthetic Rope Test Sample

Fig. 8 Tension Elongation Curve for 1 5/16" Dia., Synthetic Rope
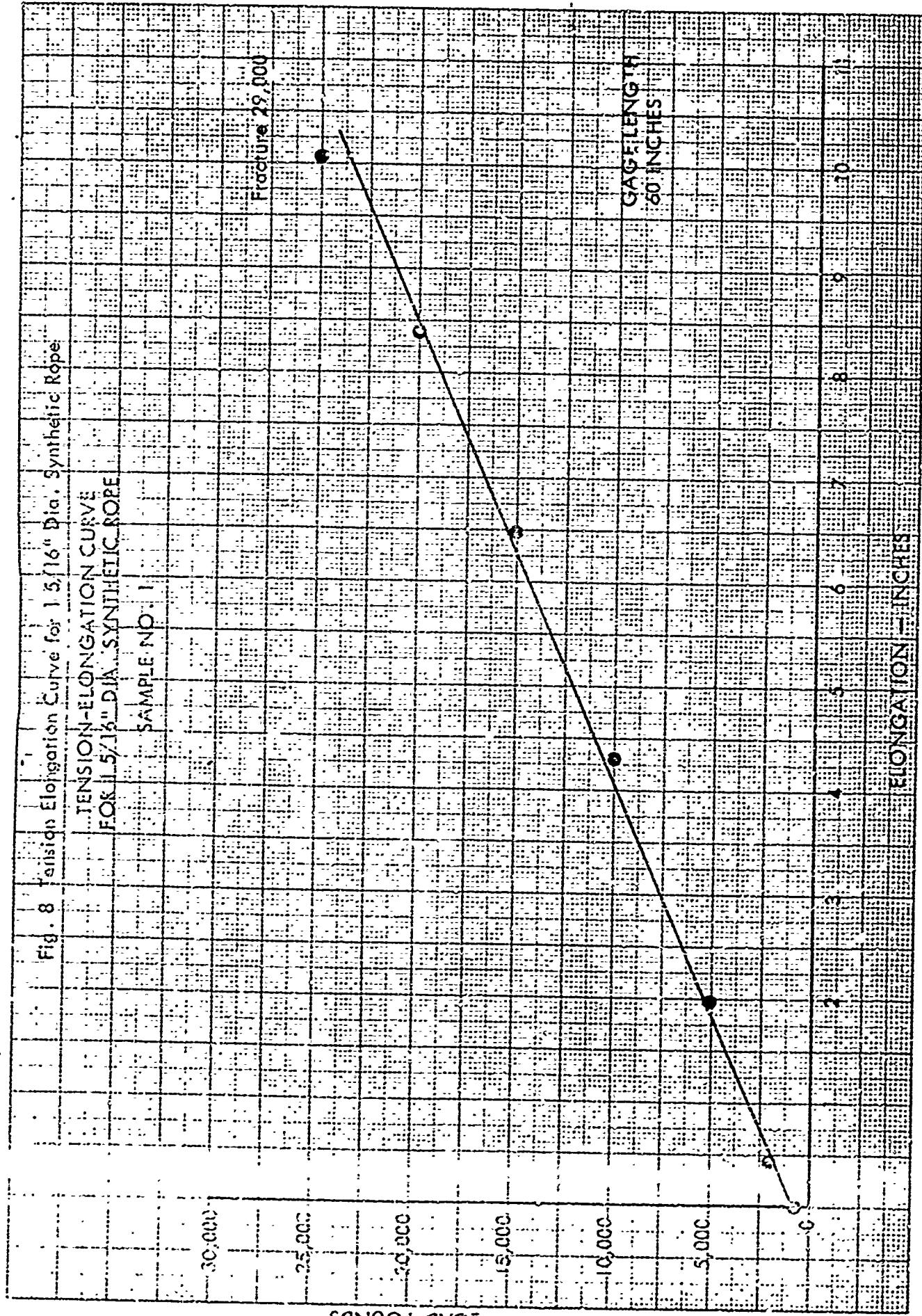
TENSION-ELONGATION CURVE
FOR 1 5/16" DIA. SYNTHETIC ROPE

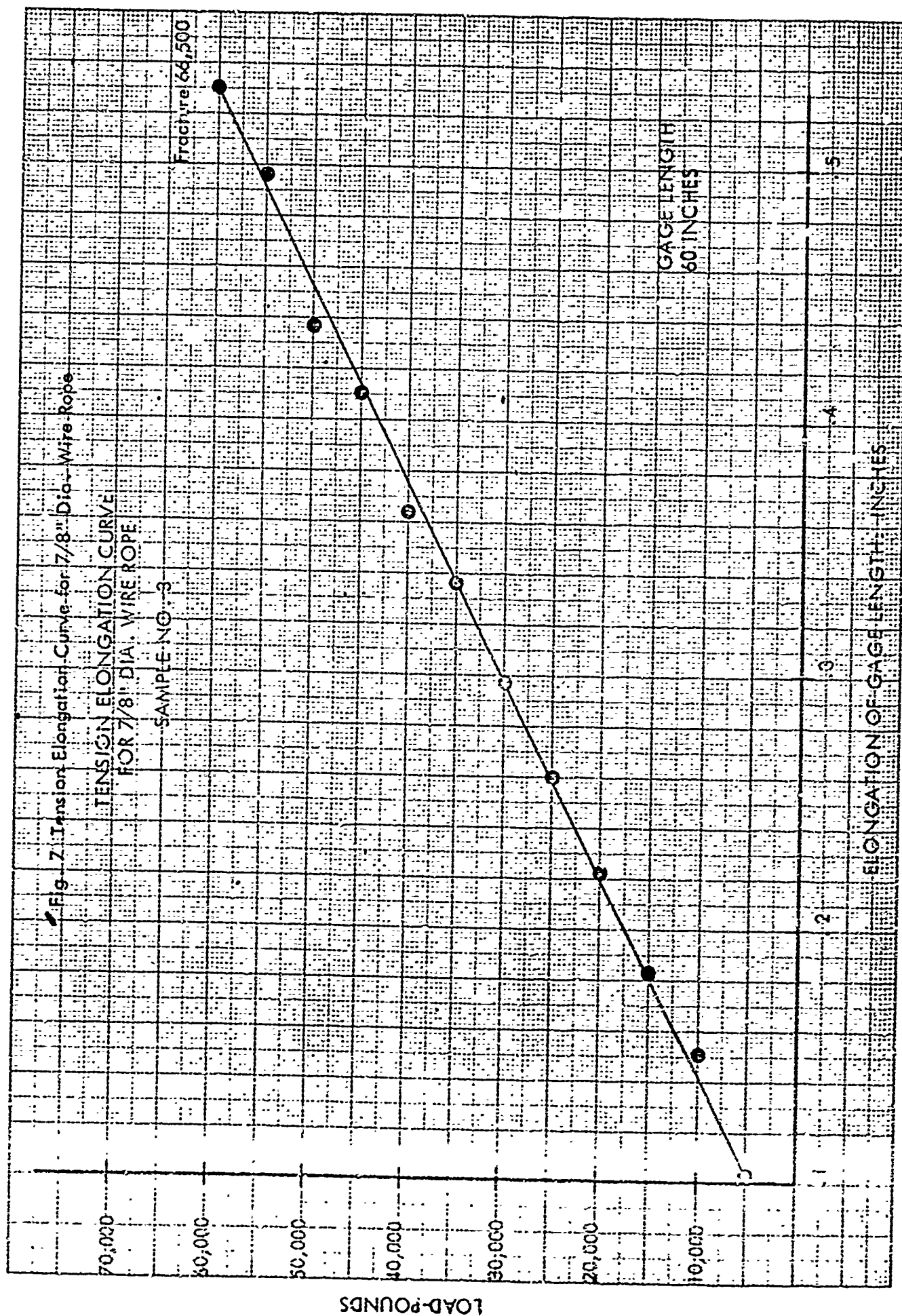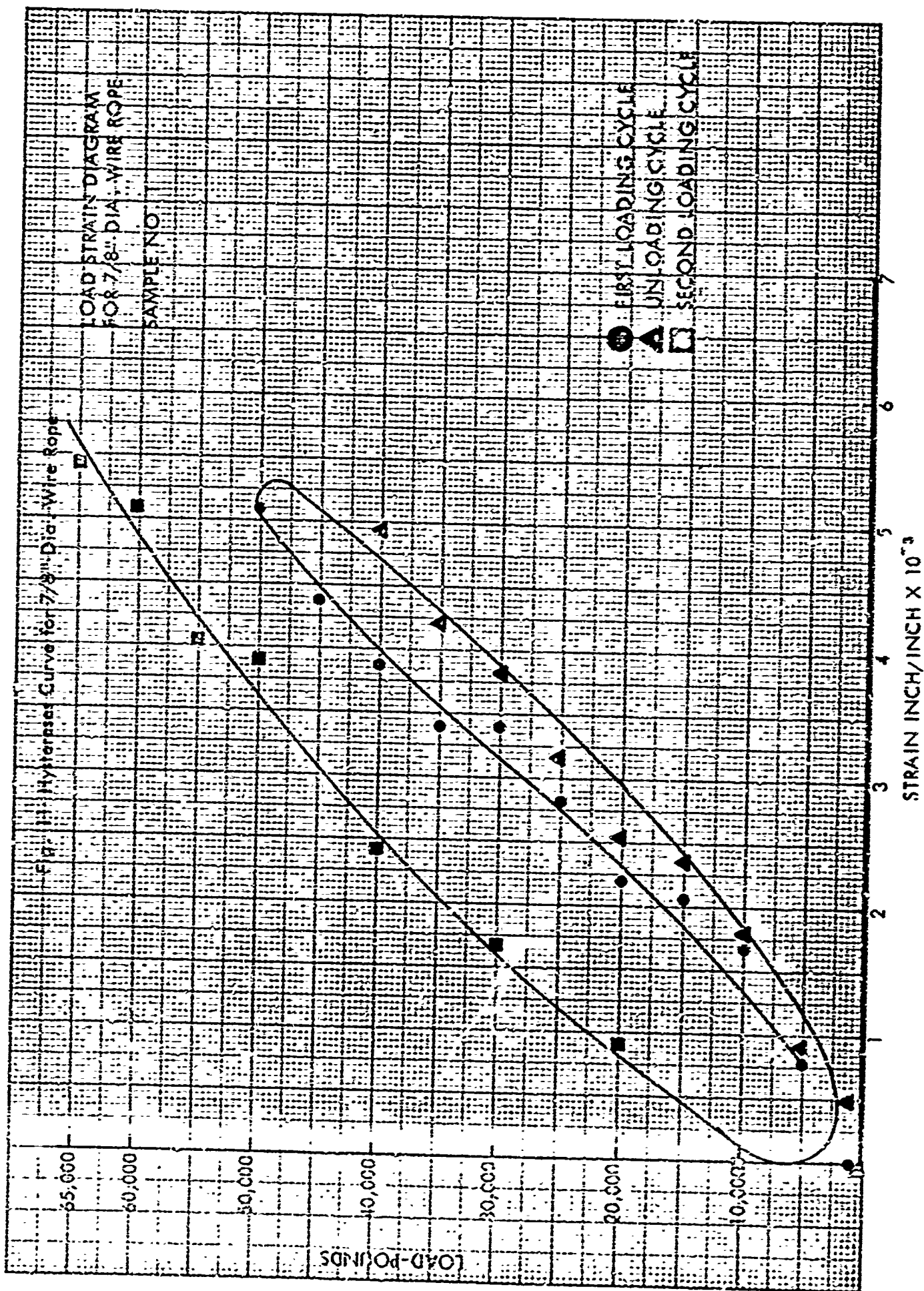SAMPLE NO. 1

Fracture 29,000

GAGE LENGTH
60 INCHES

LOAD-POUNDS

30,000

25,000

20,000

15,000

10,000

5,000

0

0   2   3   5   6   7   8   9   10   11

ELONGATION — INCHES

Fig. 7 Tension Elongation Curve for 7/8" Dia. Wire Rope

TENSION ELONGATION CURVE
FOR 7/8" DIA. WIRE ROPE
SAMPLE NO. 3

Fracture 66,500

GAGE LENGTH
60 INCHES

ELONGATION OF GAGE LENGTH-INCHES

LOAD-POUNDS

70,020
60,000
50,000
40,000
30,000
20,000
10,000

1   2   3   4   5

Fig. 9 Ultimate Fracture for the Wire Rope Test Sample No. 3 Occurred at the Edge of Fitting.

Fig. 10 Ultimate Fracture of the Synthetic Rope Test Sample No. 1 Occurred at the Junction of the Loop and the Long Length of Rope.
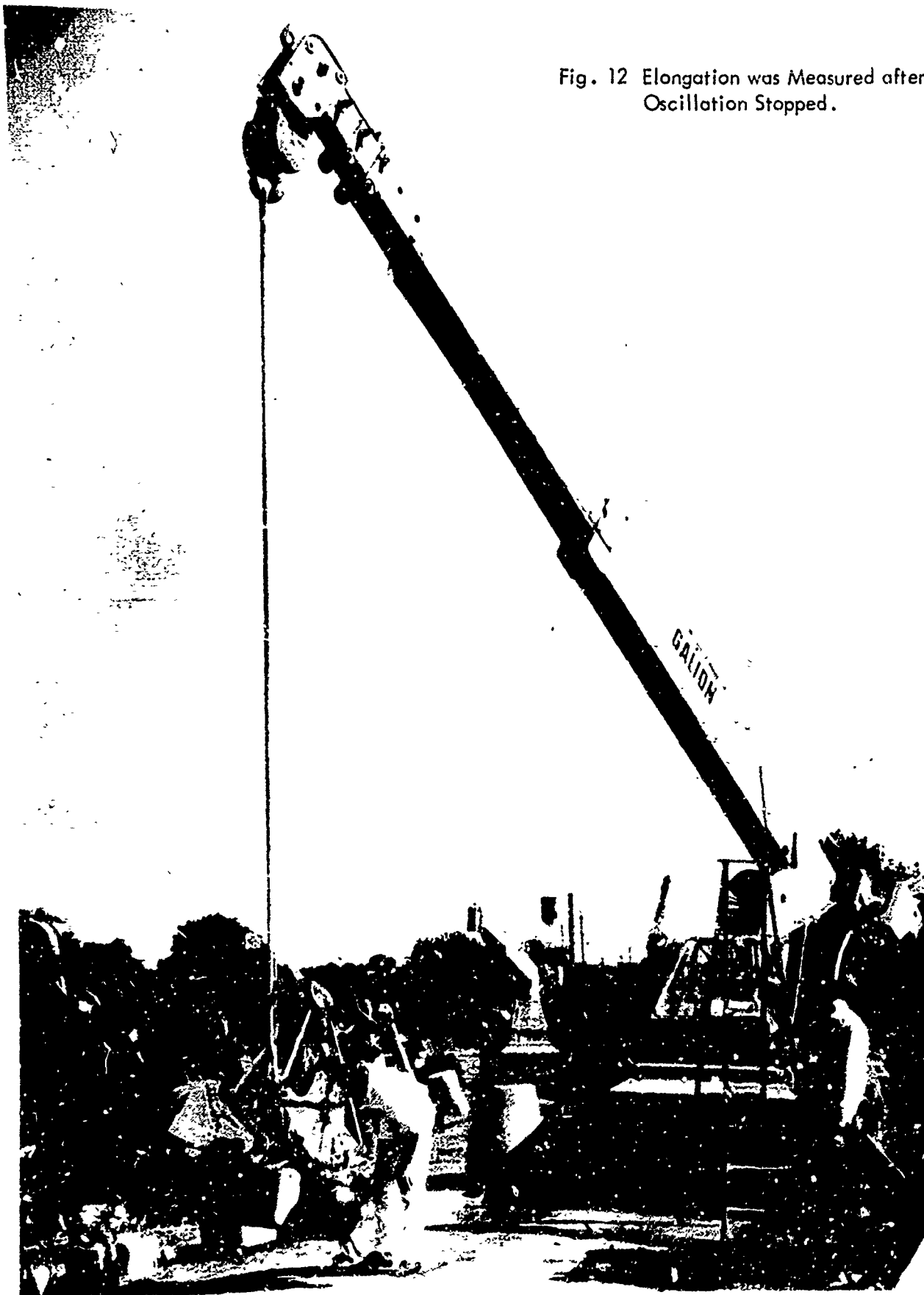
LOAD-STRAIN DIAGRAM
FOR 7/8" DIA. WIRE ROPE

SAMPLE NO.

Fig. 11. Hysteresis Curve for 7/8" Dia. Wire Rope

● FIRST LOADING CYCLE
▲ UNLOADING CYCLE
▣ SECOND LOADING CYCLE

STRAIN INCH/INCH × 10⁻³

LOAD-POUNDS

65,000
60,000
50,000
40,000
30,000
20,000
10,000

Fig. 12 Elongation was Measured after Oscillation Stopped.
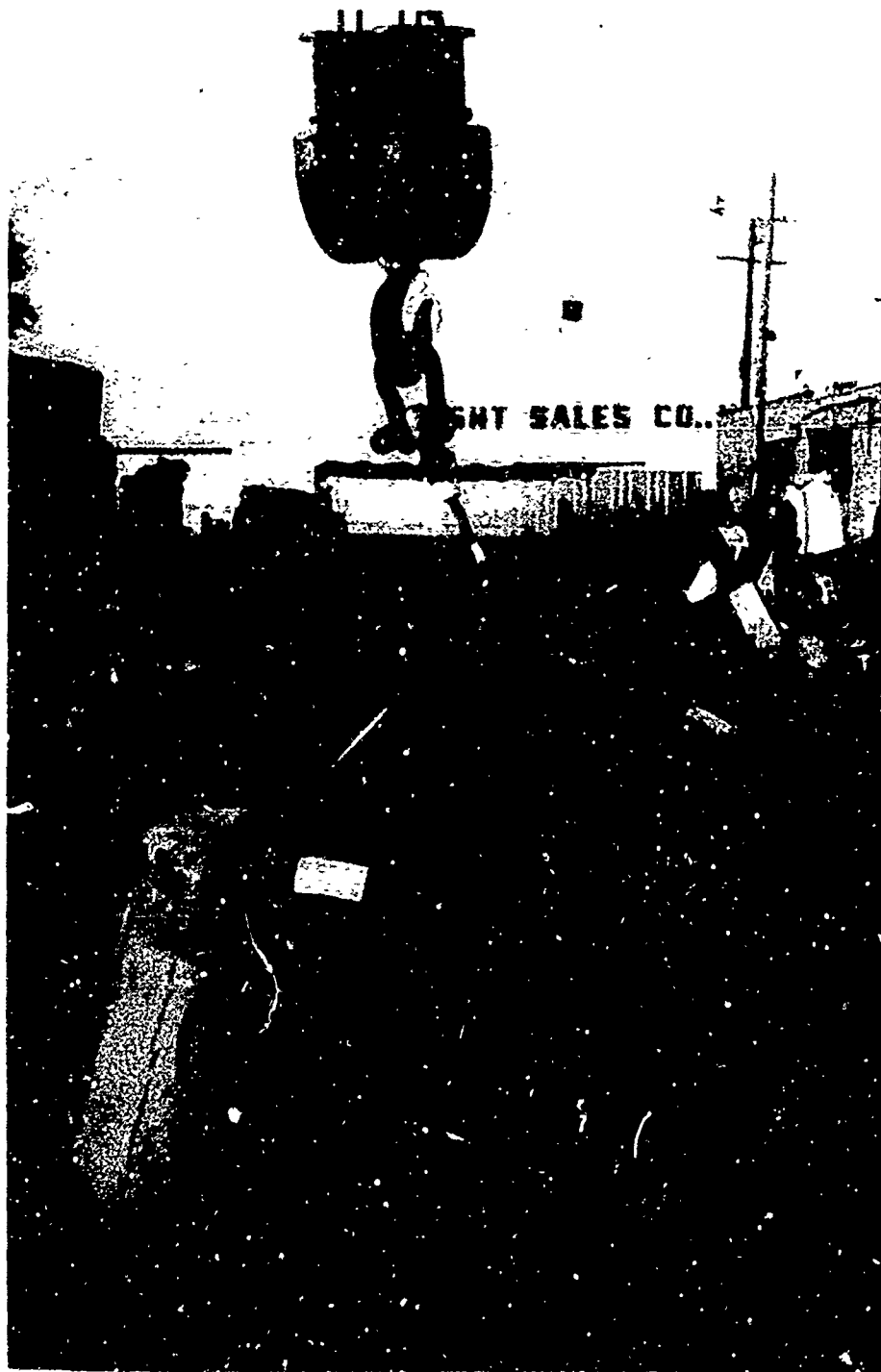
Fig 13 Typical Result Showing the Absence of Kink Formations when the Load
was Suddenly Released in the Rctation-Kink Test of the Wire Rope Samples.
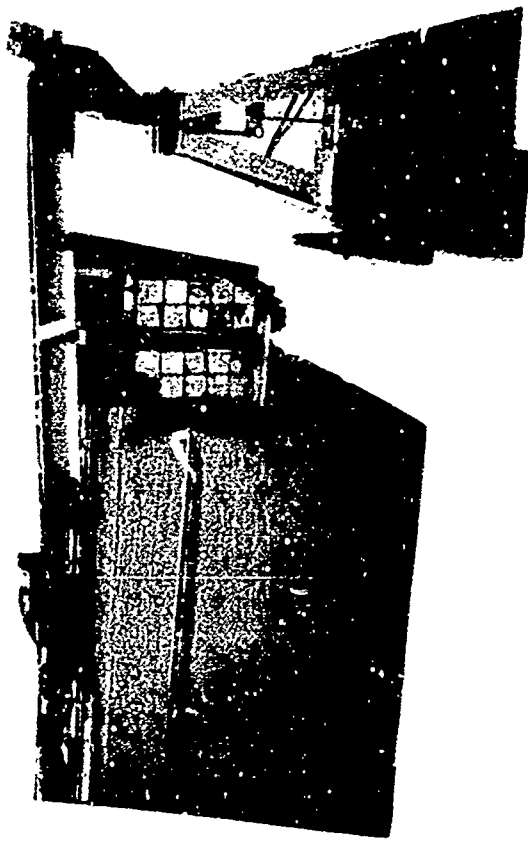
Fig. 14 Typical Result Showing the Absence of Kink Formation when the
Loads were Suddenly Released in the Rotation-Kink Test of the
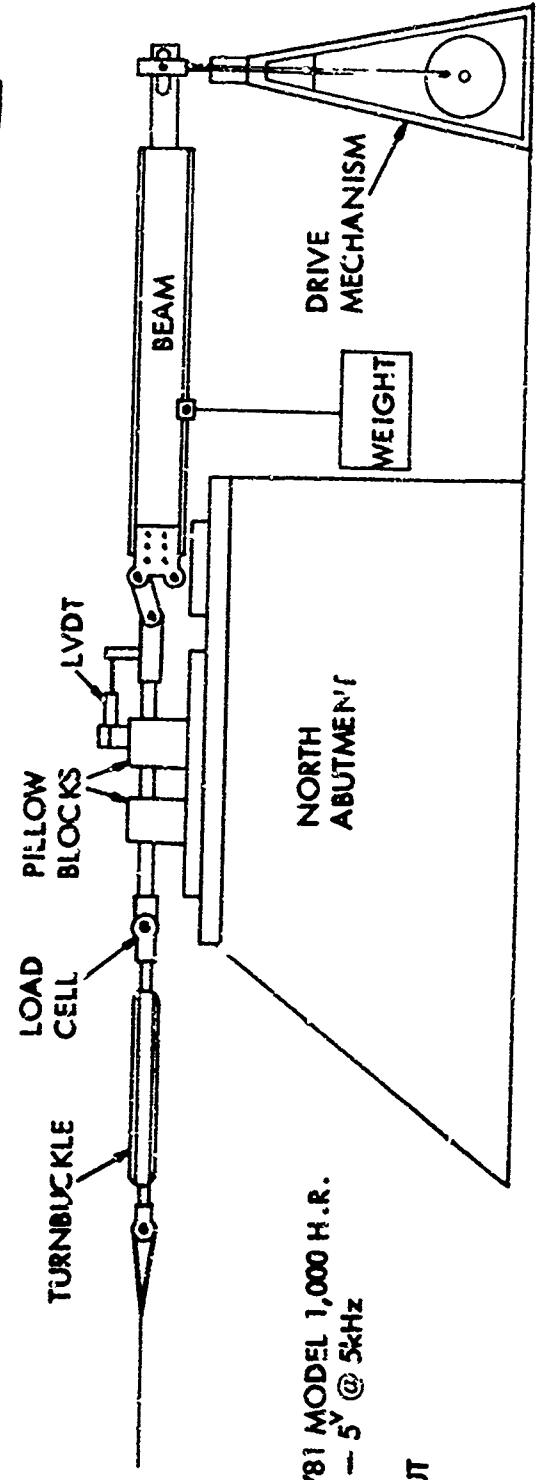Synthetic Rope Samples.

LOAD CELL

LVDT

LVDT CORE

LINEAR BEARING
PILLOW BLOCKS

LVDT SPECIFICATIONS:

SCHAWITZ #781 AND #781 MODEL 1,000 H.R.
EXCITATION VOLTAGE — 5^V @ 5kHz
MFG'S CALIBRATION
.001 IN = .0100^V OUTPUT

BEAM

DRIVE
MECHANISM

WEIGHT

NORTH
ABUTMENT

LVDT

PILLOW
BLOCKS

LOAD
CELL

TURNBUCKLE

Fig. 15 Schematic of Driver End Test Setup

TURNBUCKLE

LOAD CELL

LVDT

SOUTH ABUTMENT

60"

4"

WEIGHTS
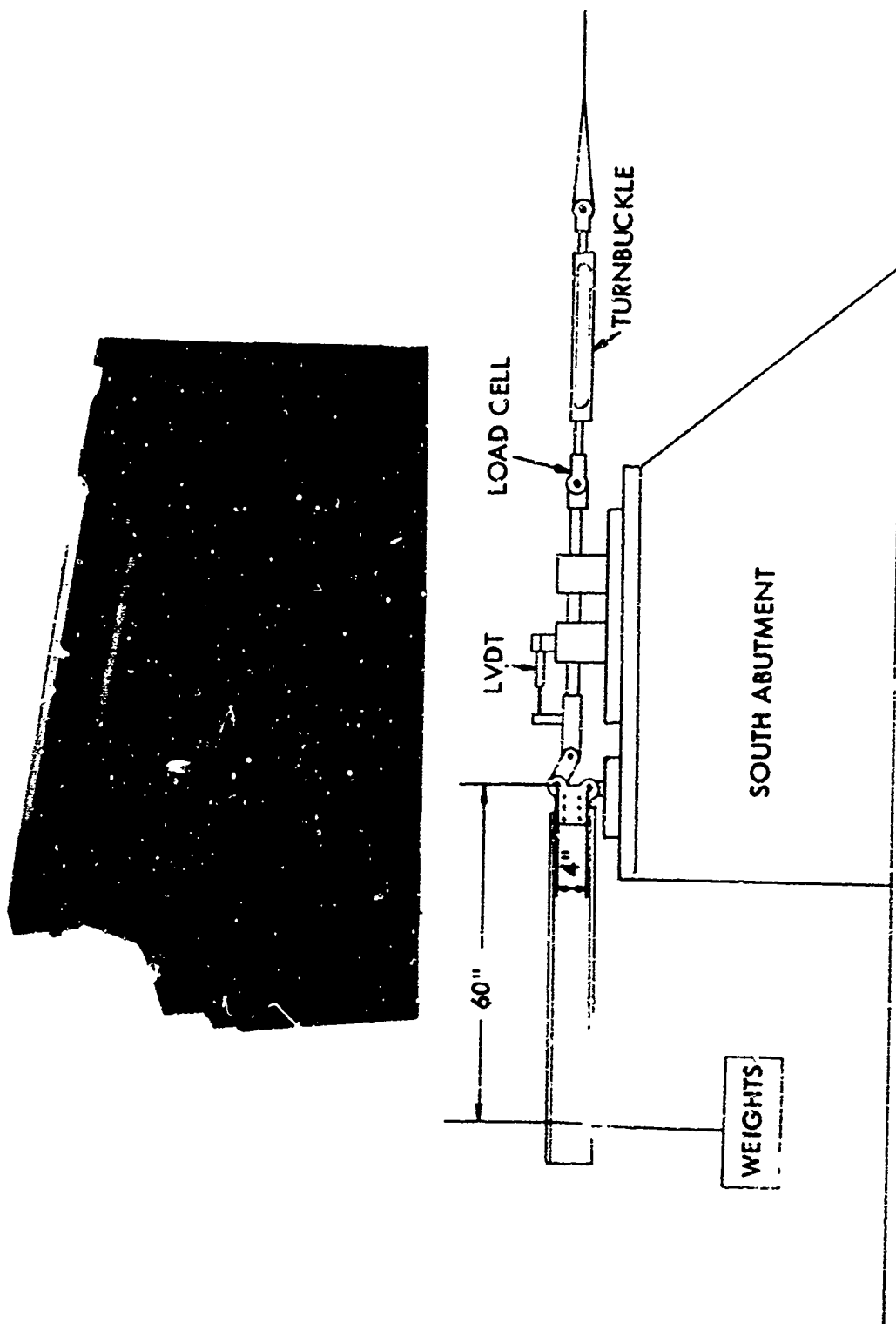
Fig. 16 Schematic of Driven End Test Setup

124' 4"

4' 8" | 28' 9" | 28' 9" | 28' 9" | 28' 9" | 4' 8"

TURNBUCKLES

TENSION MAINTAINING
SYSTEM

DRIVE

GUIDE TOWERS

TEST SAMPLE

116' 7" WIRE ROPE

117' 3" SYNTHETIC ROPE
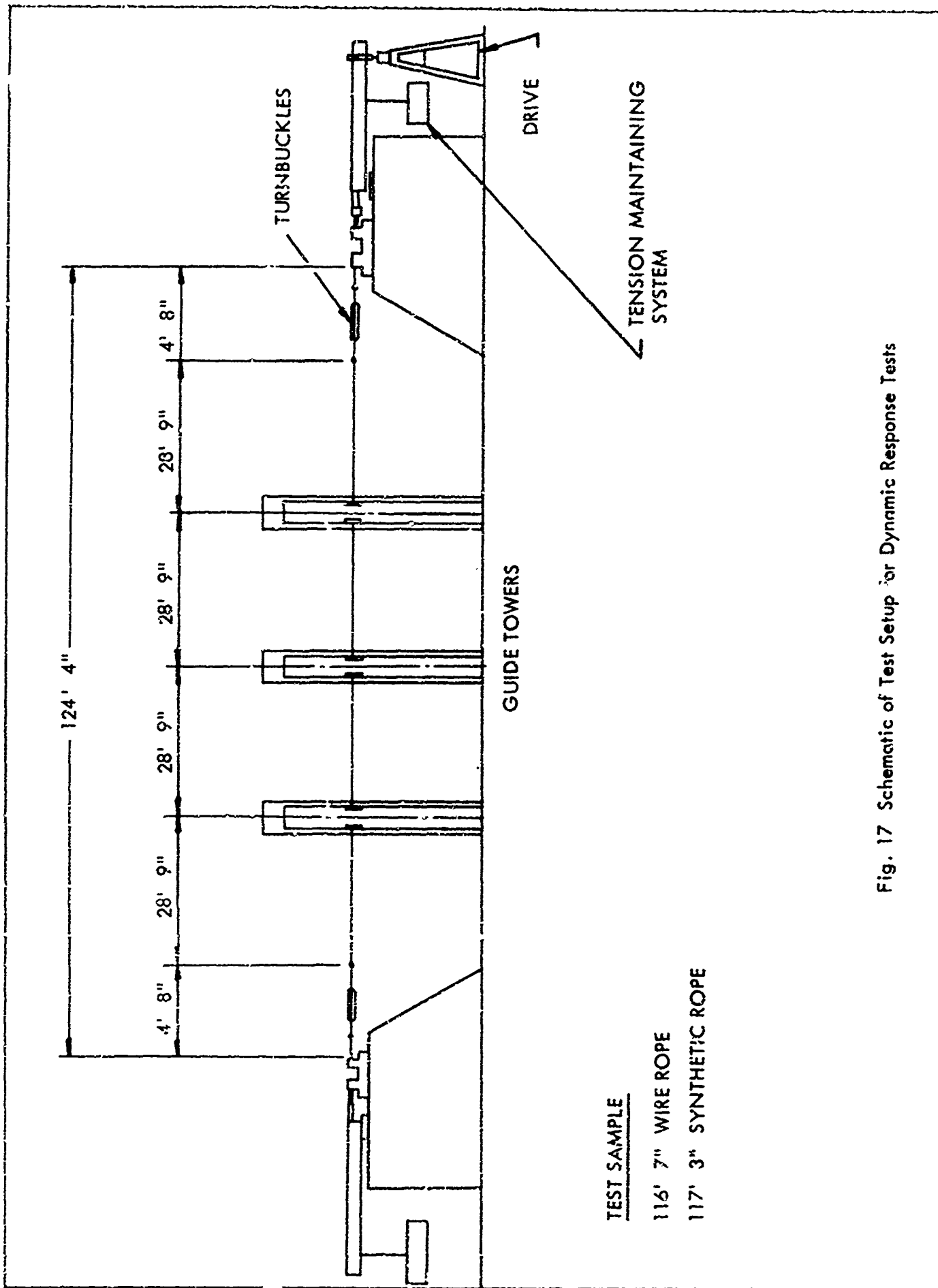
Fig. 17 Schematic of Test Setup for Dynamic Response Tests

Fig. 18
DYNAMIC RESPONSE CURVES FOR
FORCE AT DRIVING END

FORCE AT THE INPUT END / DISPLACEMENT

□ 60 MILS P-P INPUT DISPLACEMENT
△ 120 MILS P-P INPUT DISPLACEMENT
⊕ 130 MILS P-P INPUT DISPLACEMENT

WIRE ROPE

SYNTHETIC ROPE

FREQUENCY CPS

.5   1   1.5   2   2.5   3   3.5   4   4.5

Fig. 17

DYNAMIC RESPONSE CURVES

$$\frac{\text{OUTPUT DISPLACEMENT}}{\text{INPUT DISPLACEMENT}}$$

SYNTHETIC ROPE

WIRE ROPE

■ 60 MILS P-P INPUT DISPLACEMENT
▲ 130 MILS P-P INPUT DISPLACEMENT
● 120 MILS P-P INPUT DISPLACEMENT

$\left(\frac{\text{OUTPUT}}{\text{INPUT}}\right)$ DISPLACEMENT

FREQUENCY CPS

107 @ .307 CPS

INPUT DISPLACEMENT
LVDT–ATTN.–0.1
20 MILS/DIV

OUTPUT DISPLACEMENT
LVDT ATTN. 0.1
20 MILS/DIV

FORCE OUTPUT
LOAD CELL M9009
ATTN. 0.1
368 LBS/DIV

FORCE INPUT
LOAD CELL
60087
ATTN.–0.1
466 LBS/DIV

CHART SPEED
1 INCH PER SEC

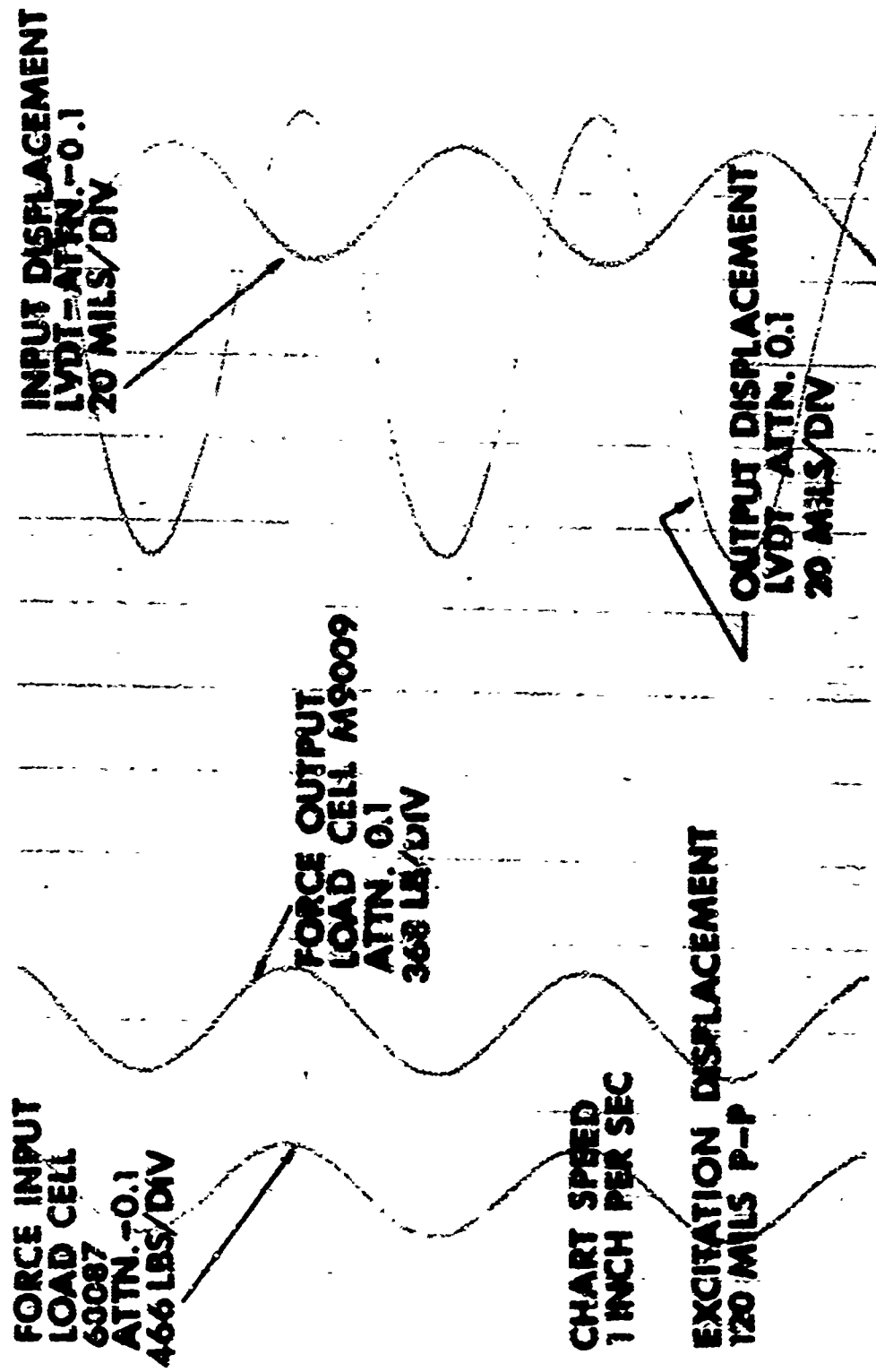EXCITATION DISPLACEMENT
120 MILS P–P

Fig. 20 Typical Oscillogram of Data for the Dynamic Response of a Wire Rope Sample

APPENDIX A

DYNAMIC EFFECTS OF LEVER ARM RATIO

Consideration I

In the ocean: a rope of undetermined length. The dampening effects of sea water were not considered.

The frequency is

$$\omega = \sqrt{\frac{K}{M}}$$

where $K = \frac{T}{\delta}$ and $\delta = \frac{TL_1}{AE}$

hence $K = \frac{AE}{L_1}$

$$\therefore \omega = \sqrt{\frac{AE}{L_1 M}}$$

Let $C = \sqrt{\frac{AE}{M}}$

then

$$\omega = C \left[\frac{1}{L_1}\right]^{\frac{1}{2}}$$

Consideration II

In the laboratory. (Refer to Fig. 16.)

$$\omega = \frac{a}{l} \sqrt{\frac{k}{m}}$$

where $k = \frac{AE}{L_2}$; $\frac{a}{l} = \frac{1}{\frac{l}{a}}$; $a < 1$

hence

$$\omega = \frac{1}{\frac{l}{a}} \sqrt{\frac{AE}{L_2 m}}$$

$$= \sqrt{\frac{AE}{\left(\frac{l}{a} L_2\right)\left(\frac{l}{a} m\right)}}$$

To obtain the same loading in the laboratory as expected on the ocean rope, a pivoting beam was used with a force multiplier of $\frac{1}{a}$.

$$M = \frac{1}{a} m$$

and

$$C = \sqrt{\frac{AE}{M}}$$

then

$$\omega = C \left[\frac{1}{\frac{1}{a} L_2} \right]^{\frac{1}{2}}$$

It can be seen that the equivalent length of ocean rope to give the same frequencies as in the laboratory test, rope is $\frac{1}{a} \times L_2$. This is equal to 15 L_2 so that 115 feet of laboratory test rope simulated an ocean rope length of 1,725 feet.

A list of symbols.

a = Beam lever arm length, short length.

A = Cross sectional area of rope.

C = Constant $\sqrt{\frac{AE}{M}}$

E = Modulus of elasticity of rope.

K = Spring constant of ocean rope.

k = Spring constant of laboratory rope.

l = Beam lever arm length, long length.

L_1 = Length of ocean rope.

L_2 = Length of laboratory rope.

M = Mass in ocean. $= \frac{1}{a} (m)$

m = Mass in laboratory.

T = Rope tension.

ω = Angular frequencies in radians per second.

δ = Elongation.

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13. ABSTRACT

A testing program was initiated by U. S. Naval Civil Engineering Laboratory to conduct dynamic tests on torque balanced wire and synthetic rope. The tests were conducted at the laboratories of Preformed Line Products Company, Cleveland, Ohio.

The scope of the work was to provide data so that a basis can be established to select the best type of line for load-handling purposes in the deep ocean environment. The tests consisted of tension vs elongation, rotation and kink formation, and longitudinal dynamic response.

The tension elongation tests yielded data typical to stranded line construction.

The rotation-kink tests revealed that negligible rotations resulted in the test cables when under load and that no kinks were formed when the load was suddenly released.

The dynamic response tests showed that the measured dynamic stresses were dependent upon the exciting frequency. The natural frequency for the synthetic rope sample was 0.3 cps and 0.5 cps for the wire rope.

The tests indicated that the highest values of combined static and dynamic stresses occur at resonance which could cause failure of the cable at points of high stress concentration.

It is recommended that some hydraulic parameters and random excitation be introduced in the future testing of this type. Stress relieving fittings should be investigated for use on load handling lines in the ocean environment.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Wire Rope						
Synthetic Rope						
Rotation						
Torque						
Tension Tests						
Elongation						
Longitudinal Vibration						
Strains						
Static Loads						
Static Stresses						
Dynamic Loads						
Dynamic Response						
Dynamic Stresses						
Load-Handling Lines						
Rope Kinking						
Tension and Elongation Tests						
Rotation and Kink Tests						